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DESCRIPTION

METHOD FOR FORMING THIN FILM AND APPARATUS THEREFOR

TECHNICAL FIELD

The present invention relates to a thin film formation method of solar cells, preferably applied to mass production, and thin film formation apparatus.

BACKGROUND ART

There are great expectations for solar cells as clean energy sources, whereas further reduction of cost is necessary to attempt extensive diffusion. For this purpose, a thin film formation apparatus capable of uniform deposition of high quality amorphous silicon (hereafter "a-Si") thin film on larger substrates is desired.

Moreover, a tandem structure solar cell, where a-Si solar cell is stacked on microcrystalline silicon (hereafter, "μc-Si") solar cell, gives higher conversion efficiency than a-Si used individually. Therefore, a thin film formation apparatus for the deposition of μc-Si thin film is also desired.

As an art of thin film formation apparatus, Japanese unexamined patent publication No. S59-014633 discloses an art of a capacitively-coupled parallel plate type plasma CVD apparatus.

DISCLOSURE OF INVENTION

In general, parallel plate type plasma CVD apparatus consists of a pair of electrode plates, one connected to a high frequency power source and the other one grounded, facing to each other with a prescribed space apart as a discharge region, and forms thin film on the surface of a substrate placed on the grounded electrode plate. In parallel plate type plasma CVD apparatus, only one substrate or a substrate divided into a number of small pieces can be placed on either one of the pair of electrode plates. This is due to different effect, the electrode plates connected to the high-frequency power source and the grounded one receive from plasma. Therefore, in order to form thin film on a number of substrates simultaneously, the chamber of above-mentioned plasma CVD apparatus must be provided with plural pairs of electrodes in advance. Such a chamber needs a large internal space. Moreover, the maintenance becomes difficult if three or more pairs of electrodes are to be provided. Therefore, in reality, it is appropriate to use an apparatus having a chamber provided with up to two pairs of electrodes, and to treat maximum of two substrates at a time.

Moreover, due to a principal limitation, each electrode plates in parallel plate type plasma CVD apparatus must be larger than the substrate. Thereby, much larger electrode plates are needed in order to deposit on much larger substrates, however, it is difficult to generate uniform plasma between large electrode plates. Because of such a problem, it is extremely difficult to form thin films on large substrates with uniform thickness and characteristics.

The present invention has been achieved in view of above problems. The objective of the present invention is to provide a thin film formation method and an apparatus thereof, by which many plasma sources can be arranged in a limited space, and uniform plasma can be generated within each discharge regions, resulting in uniform deposition of high quality thin film on a large substrate.

According to the first aspect of the present invention, a thin film formation method is composed of plural antenna elements, consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, arranging a number of above antenna elements in a chamber so that the first and the second linear conductors are placed alternately in plane with equal intervals, forming one or more array antenna(s), connecting the second ends of each of the above first linear conductors to high-frequency power source, grounding the second ends of each of the above second linear conductors, installing plural substrates on both sides of and in parallel to respective above array antenna(s) with a space between the array antenna(s) and the substrates comparable to the above intervals between the linear conductors, and depositing thin film on respective above substrates. Preferably, the pressure in the above chamber is kept at 60Pa or less.

According to the second aspect of the present invention, a thin film formation method is composed of plural antenna elements, consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, arranging a number of above plural antenna elements in a chamber so that the first and the second linear conductors are placed alternately in plane with equal intervals, forming one or more array antenna(s), connecting the second ends of each of the above first linear conductors to high-frequency power source, grounding the second ends of each of the above second linear conductors, and depositing thin film on respective substrates while maintaining the pressure in the above chamber to be at 60Pa or less .

In the above thin film formation method, preferably the above substrates are reciprocated in the direction parallel to the above array plane and perpendicular to the above first and the second linear conductors.

According to the third aspect of the present invention, a thin film formation apparatus is provided with a chamber equipped with an inlet port to introduce source gas and an exhaust port for evacuation, plural antenna elements consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, the above first and the second linear conductors placed alternately in plane with equal intervals, the second ends of each of the above first linear conductors connected to high-frequency power source, the second ends of each of the above second linear conductors being grounded, one or more array antenna(s) placed in the above chamber, and with plural substrate holders provided so as to place plural substrates on both sides of and in parallel to respective above array antenna(s) with a space between the array antenna(s) and the substrates comparable to the above intervals between the linear conductors.

The above thin film formation apparatus is preferably further provided with dielectric covering the above respective first linear conductor.

According to the fourth aspect of the present invention, a solar cell production method is composed of plural antenna elements, consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, arranging a number of above antenna elements in a chamber so that the first and the second linear conductors are placed alternately in plane with equal intervals, forming one or more array antenna(s), connecting the second ends of each of the above first linear conductors to high-frequency power source, grounding the second ends of each of the above second linear conductors, installing plural substrates on both sides of and in parallel to respective above array antenna(s) with a space between the array antenna(s) and the substrates comparable to the above intervals between the linear conductors, and depositing thin film on respective above substrates. Preferably, the pressure in the above chamber is maintained at 60Pa or less.

According to the fifth aspect of the present invention, a solar cell production method is composed of plural antenna elements, consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, arranging a number of above antenna elements in a chamber so that the first and the second linear conductors are placed alternately in plane with equal intervals, forming one or more array antenna(s), connecting the second ends of each of the above first linear conductors to high-frequency power source, grounding the second ends of each of the above second linear conductors, and depositing thin film on respective substrates while maintaining the pressure in the above chamber at 60Pa or less .

In the above solar cell production method, preferably the above substrates are reciprocated in the direction parallel to the above array plane and perpendicular to the above first and the second linear conductors.

According to the sixth aspect of the present invention, a solar cell production apparatus is provided with a chamber equipped with an inlet port to introduce source gas and an exhaust port for evacuation, plural antenna elements consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, the above first and the second linear conductors placed alternately in plane with equal intervals, the second ends of each of the above first linear conductors connected to high-frequency power source, the second ends of each of the above second linear conductors being grounded, one or more array antenna(s) placed in the above chamber, and with plural substrate holders provided so as to place plural substrates on both sides of and in parallel to respective above array antenna(s) with a space between the array antenna(s) and the substrates comparable to the above intervals between the linear conductors.

The above solar cell production apparatus is preferably further provided with dielectric covering the above respective first linear conductor.

According to the seventh aspect of the present invention, solar cell is provided with thin films deposited on the surface of substrates, with plural antenna elements consisted of two linear conductors where the first ends of the first and the second linear conductors are electrically connected to each other, the above first and the second linear conductors placed alternately in plane with equal intervals, forming one or more array antenna(s), the second ends of each of the above first linear conductors connected to high-frequency power source, the second ends of each of the above second linear conductors being grounded, and by maintaining the pressure in the above chamber at 60Pa or less.

The above thin film is preferably further deposited with above substrates reciprocated in the direction parallel to the above array plane and perpendicular to the above first and the second linear conductors.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a schematic front view of a thin film formation apparatus according to an embodiment of the present invention.

Fig. 2 is a side view of the thin film formation apparatus according to the above embodiment.

Fig. 3 is a cross sectional view of an antenna element according to the above

embodiment.

Fig. 4A is a schematic drawing showing a state of forming a thin film in a case where uniform thin film is formed.

Fig. 4B is a schematic drawing showing a state of forming a thin film in a case where nonuniform thin film is formed.

Fig. 4C is a schematic drawing showing a state of forming a thin film and the relation between a stroke S of a substrate and the distance P between the linear conductors.

Fig. 5A is a diagram showing the experimental result of the relation between the distance between the antenna elements and the substrate and the properties of the thin film

Fig. 5B is a diagram showing the experimental result of the relation between the distance between the antenna elements and the substrate and the growth rate of the thin film

Fig. 5C is a diagram showing the experimental result of the relation between the pressure in the chamber and the properties and the growth rate of the thin film

BEST MODE FOR CARRYING OUT THE INVENTION

A thin film formation apparatus according to one embodiment of the present invention will be described hereinafter with reference to Figs. 1 and 2. A thin film formation apparatus 1 is an antenna-type inductively-coupled plasma CVD apparatus, moreover, is relatively large in size to deposit on large (large area) substrates, suitable for the production of solar cells for the use in photovoltaic power generation, and is provided with a film-deposition chamber 10, array antennas 20 installed in the above film-deposition chamber 10 and substrate holders 50 to hold substrate 40 for deposition.

The film-deposition chamber 10 is composed of the a spatial size, with enough height and width to deposit on large substrates 40, for example more than 1m square in size, and with enough depth to achieve simultaneous deposition on plural (six substrates in the illustrated example) of such substrates.

Plural sets of array antennas 20 (three sets of array antennas, 20a, 20b and 20c in the illustrated example) are placed in the film-deposition chamber 10, and each array antenna 20 consists of plural (six in the illustrated example) antenna elements 30.

As shown in Fig. 3, each antenna element 30 consists of two linear conductors, the powered conductor 31 and the grounded conductor 35, placed parallel to each other and electrically connected to adjacent ones at one end (for example at the bottom end) with a conductor 38 to form a parallel line in back and forth in almost U-shape. The

other end of above one of the powered conductor 31 (namely, the upper end) is a high-frequency power feeding portion to be connected to a high-frequency power source, and the other end of the grounded conductor 35 (namely, the upper end) is a grounding portion to be grounded.

A solid rod is used as the powered conductor 31 and the high-frequency power feeding portion, for example, pass through a feed-through 32 made of dielectric such as Al_2O_3 provided on the wall of film-deposition chamber 10, and is connected to a high-frequency power source 11 placed outside the film-deposition chamber 10. Furthermore, tubular dielectric pipe 33 such as Al_2O_3 is provided around the powered conductor 31 inside the film-deposition chamber 10, and the thickness of above dielectric pipe 33 is to be suitably determined.

A tubular pipe with many holes 36 on the surface is used as a grounded conductor 35, which upper end is grounded to the inner surface of the above film-deposition chamber 10 and is connected to a gas supply source 12 placed outside the film-deposition chamber 10. Therefore, the grounded portion of a tubular grounded conductor 35 of respective antenna element 30 functions as the source gas introduction port of the above film-deposition chamber 10.

The above plural antenna elements 30 (six in the illustrated example) are arranged in such a way that each high frequency supply portion and each grounded portion, namely the powered conductors 31 and the grounded conductors 35, respectively, are alternately arranged. All powered conductors 31 and grounded conductors 35 are arranged on the same plane (hereafter, "array plane") with even intervals. Each array antenna 20 is constituted in such a way explained above. Plural array antennas 20 (three sets of array antennas, 20a, 20b and 20c in the illustrated example) are placed parallel to each other in the film-deposition chamber 10 with a prescribed intervals in between. Therefore, respective array plane is placed in the film-deposition chamber parallel to each other with a prescribed interval in between.

The above substrate holder 50 holds a pair of substrates 40 on which thin film is to be deposited at both sides of the array antenna 20, keeping both of the substrates 40 parallel to the above array plane, and moreover, positions the distance D between the array antenna 20 and the substrates 40 (hereafter, "antenna-substrate distance D ", see Fig. 2) to be comparable (specified later) to the distance P between the powered conductors 31 and the grounded conductors 35 (see Fig. 1: for example 35mm). Since three sets of array antennas 20a, 20b and 20c are illustrated as an example, the substrate holder 50 holds one of the substrates 40 each on both sides of respective array antenna 20, resulting in six substrates 40 in total. All substrates 40 are positioned in parallel to

the array plane of corresponding array antenna 20, and in such a way that the antenna-substrate distance D is set comparable to the distance P between the powered conductors 31 and the grounded conductors 35 (about 35mm).

Such substrate holder 50 is constituted so that the substrate holder 50 can be carried in and out of the film-deposition chamber 10 supported by an appropriate carrier (not shown), in order to enable being carried in and out of the film-deposition chamber 10 while holding all of above substrates 40. For this purpose, although not shown in Fig. 1, the side plates on the left and the right sides of the film-deposition chamber 10 are designed to be capable of opening and closing, in such a way while either one of left or right (for example, left) side plate is opened and the substrate holder 50 is carried in the film-deposition chamber 10, the other one (for example, right) side plate is opened and the substrate holder 50 is carried out. Moreover, although not shown, the film-deposition chamber 10 is provided with, for example on the lower part, an exhaust port for evacuation.

Furthermore, the above film-deposition chamber 10 is provided with a heat control system 13 to control the temperature of the above substrate 40 from rising during deposition. The heat control system 13 consists of, for example, an appropriate heat absorbent to absorb heat from the respective substrates 40 via heat radiation or heat conduction, and with a mechanism to release the heat absorbed by the absorbent to the side walls and such of the film-deposition chamber 10 by heat radiation or heat conduction. Besides, the heat control system 13 may be comprised of only a heat absorbent provided with a cooling function using a fluid as a medium, furthermore, without the heat absorbent and only by a waste heat function where the heat inside the film-deposition chamber 10 is forced to be released outside.

In case of using the above thin film formation apparatus 1 constituted in such a way explained above, the deposition process is performed maintaining the pressure in the above film-deposition chamber 10 at 60Pa or less.

That is to say, first, in the film-deposition chamber 10, all (six) substrates 40 are positioned in parallel to the corresponding array planes of the array antennas 20 (20a, 20b and 20c), with the antenna-substrate distance D set comparable to the distance P (about 35mm) between the powered conductors 31 and the grounded conductors 35 ($D \cong P$) by the substrate holder 50.

Next, the above source gas is introduced inside all of the grounded conductors 35 of the respective antenna elements 30 of the array antennas 20 (20a, 20b and 20c) from the gas supply source 12 placed outside the film-deposition chamber 10. The source gas is introduced into the film-deposition chamber 10 through the holes 36 on

the grounded conductor 35, filling the film-deposition chamber 10, and the pressure inside the film-deposition chamber 10 is controlled to be appropriate at 60Pa or less.

Then, the deposition process is performed by maintaining the pressure inside the film-deposition chamber 10 to be appropriate at 60Pa or less, introducing high frequency power (for example, VHF power at 85MHz) to all the powered conductors 31 of the respective antenna elements 30 of the array antennas 20 (20a, 20b and 20c) from the high-frequency power source 11 placed outside the film-deposition chamber 10, and generating plasma around all powered conductors 31 and grounded conductors 35, connected electrically by conductors 38.

As a result of performing the above deposition process, objective thin film is deposited on the surface of all (six) substrates 40 as partially shown in Fig. 4A. The thin film is in the form of amorphous or microcrystalline structure.

When SiH_4 gas was practically used as the source gas for the deposition process, microcrystalline silicon (μc-Si) thin films were deposited on all (six) substrates 40 in the film-deposition chamber 10, and the film properties of the thin films were confirmed to be uniform over the whole surface of the substrates 40. Besides, as higher high frequency power above 1kW per square meter is required for microcrystalline silicon deposition, such a phenomenon happens where the temperature of the respective substrates 40 rises by being exposed to high density plasma during deposition. However, as the film-deposition chamber 10 is provided with the heat control system 13, the film properties were confirmed not being deteriorated by the temperature rise of the substrates 40 during the deposition process, due to the effect of the heat control system 1.

Furthermore, by changing the above antenna-substrate distance D during the deposition process, results shown in Fig. 5A and Fig. 5B were obtained.

As shown in Fig. 5A, when the antenna-substrate distance D is about 35mm, comparable to the distance P between the powered conductors 31 and the grounded conductors 35, the signal ratio of microcrystalline silicon (μc-Si) to amorphous silicon (a-Si) is the highest, showing good crystallinity and high quality film being obtained. It is shown that even with larger antenna-substrate distance D, up to about 47mm, considerably high quality films are obtained. Besides, the antenna-substrate distance D shorter than 35mm is not shown in Fig. 5A, however, it was confirmed that considerably high quality films are obtained down to about 17mm. From the results obtained above, it was found that the optimum value of antenna-substrate distance D is about 35mm which is comparable to the distance P between the powered conductors 31 and the grounded conductors 35, and about ±50% of the above optimum value (about

17mm to about 47mm) was found to be the permissible range of the antenna-substrate distance D judging from the film quality. This supports that electromagnetic field efficiently induces ionization reaction as long as the antenna-substrate distance D is within the above permissible range.

Fig. 4B shows the experimental results of deposition when the antenna-substrate distance D is close to the lower limit of the permissible range of the optimum value (about 35mm). The thickness of the deposited film on the substrates 40 is thicker at the positions corresponding to the positions of the powered conductors 31 and the grounded conductors 35, while it becomes thinner as the positions become apart from the powered conductors 31 and the grounded conductors 35, and as a result, a film with a striped pattern with thick and thin parts arranged alternately, with constant intervals corresponding to the powered conductors 31 and the grounded conductors 35, is formed on the respective substrates 40.

Accordingly, the formation of above striped pattern can be avoided by repeatedly reciprocating the substrates 40 for an appropriate stroke during deposition in the direction parallel to the array plane and perpendicular to the powered conductors 31 and grounded conductors 35. The length of reciprocating stroke S is, as shown in Fig. 4C, preferably about twice the distance P (about 35mm) between the powered conductors 31 and the grounded conductors 35 ($S \cong 2P$), that is to say, corresponding to the distance between adjacent array elements 30 of the array antenna 20 (70mm). This is because, for example, even if the depositing conditions on the substrates 40 differs between the positions corresponding to the powered conductors 31 and the grounded conductors 35 in a strict sense, by reciprocating between two points which are considered to be in the same deposition conditions, such as between one powered conductor 31 and another adjacent powered conductor 31, or between one grounded conductor 35 and another adjacent grounded conductor 35, it is expected to for uniform microcrystalline thin film on the surface of respective substrates 40 without a striped pattern.

Experiment was carried out in such a way where the substrates 40 were reciprocated during deposition for a stroke corresponding to the distance between adjacent array elements 30 of array antenna 20 (70mm), and it was confirmed that uniform microcrystalline thin film can be formed on the surface of respective substrates 40 without a striped pattern.

Therefore, it was confirmed that high quality microcrystalline film can be formed with uniform thickness distribution without reciprocating the substrates 40 during deposition, if the antenna-substrate distance D is set to a value, within the

permissible range and near the optimum value, where the optimum value is comparable to the distance between the powered conductors 31 and the grounded conductors 35 (about 35mm) and the permissible range is about ±50% of the optimum value. Moreover, even if the antenna-substrate distance D is apart from the optimum value, as long as it is set within the permissible range, it was confirmed to be able to form high quality microcrystalline film uniformly without a striped pattern by repeatedly reciprocating the substrates 40 for appropriate stroke during deposition.

Furthermore, as shown in Fig. 5B, the deposition rate shows a maximum value when the antenna-substrate distance D is about 40mm, and becomes lower when the antenna- substrate distance D is longer or shorter than this value.

While the above film quality showed the optimum value of the antenna-substrate distance D to be about 35mm, comparable to the distance between P between the powered conductors 31 and the grounded conductors 35 as shown in Fig. 5A, the deposition rate shows the maximum value when the antenna-substrate distance D is about 40mm as shown in Fig. 5B, that is longer than the optimum value for film quality which is about 35mm. One of the reasons for this is suggested to be due to the electromagnetic field, generated around the above powered conductors 31 and the grounded conductors 35 of above array antenna 20, pass through the substrates 40 or leak out when the substrate 40 is too close to the array antenna 20.

Accordingly, in case of shortening the antenna-substrate distance D than the optimum value (about 35mm) within the permissible range, it is preferred to provide metal backing-plates at the back sides of the substrates 40. This is because VHF power can be made efficiently absorbed into plasma as the metal backing-plates reflect the electromagnetic field.

Furthermore, by varying the pressure in the film-deposition chamber 10 during deposition process, results shown in Fig. 5C were obtained.

As shown in Fig. 5C, when the pressure in the film-deposition chamber 10 becomes about 20Pa or less, suddenly the signal ratio of μc-Si to a-Si increases, resulting in high cyrstallinity and high quality films. Moreover, the deposition rate also becomes slightly faster when the pressure in the film-deposition chamber 10 is lower. It is not shown in Fig. 5C, however, when the pressure in the film-deposition chamber 10 exceeds 60Pa, a film with a striped pattern with thick and thin parts arranged alternately is formed on the respective substrates 40, with constant intervals corresponding to the powered conductors 31 and the grounded conductors 35, where it becomes thicker at the positions corresponding to the positions of the powered conductors 31 and the grounded conductors 35, and becomes thinner as the positions

become apart from the powered conductors 31 and the grounded conductors 35. And if the source gas pressure in the film-deposition chamber 10 is 60Pa or less, then it was confirmed that such a striped pattern is practically not formed, high quality film is practically obtained, and useful deposition rate is obtained.

The above-mentioned various matters were confirmed experimentally for μc-Si thin film deposition, however, the same tendency as the confirmed matters obtained in such experiments was found when depositing other thin films (such as a-Si, silicon nitride, diamond like carbon etc.).

Moreover, in the above explanation, as the distance P between the powered conductors 31 and the grounded conductors 35 was about 35mm, the optimum value for antenna-substrate distance D was about 35mm, and the permissible range was between about 17mm and about 47mm, however, if the distance P between the powered conductors 31 and the grounded conductors 35 is other than this value, as a matter of course, the optimum value of the antenna-substrate distance D depends on the above value, and the permissible range becomes about ±50% of the above antenna-substrate distance D.

As mentioned above, by using the thin film formation apparatus 1 (antenna-type inductively-coupled plasma CVD apparatus) for deposition, simultaneous deposition of thin films on the surface of two substrates 40 per one set of array antenna 20, one substrate per one side of array antenna 20, can be performed. As shown in the figures, when the thin film formation apparatus 1 is provided with three sets of array antennas 20a, 20b and 20c, simultaneous deposition of thin films on the surface of two substrates per each array antenna 20, total of six of substrates 20 can be carried out.

The above respective array antenna 20 is composed of plural antenna elements 30, where the number of antenna elements 30 (six in the example shown in figures) can be increased to any number in principle up to the limitation of the dimension of the film-deposition chamber 10. Therefore, there is no principle limit in size in the width direction in Fig. 1 in order to increase the size of respective substrates 40.

On the other hand, the length of the powered conductors 31 and the grounded conductors 35 of respective antenna elements 30 has to be elongated in order to increase the size of respective substrates 40 in the height direction in Fig. 1. The dielectric pipe 33 provided around the powered conductors 31 is effective to elongate the length of the powered conductors 31 and the grounded conductors 35. In case there is no dielectric pipe 33, as high-frequency power is supplied to the powered conductors 31 from the upper end, plasma is only generated for a short distance form the upper part. By using the dielectric pipe 33 when the linear conductors are elongated, the region plasma is

generated will be elongated toward the bottom part depending on the length of the conductors.

By controlling the thickness of the dielectric pipe 33 suitably depending on the positions, the plasma density can be maintained uniform. Moreover, as changing the thickness of dielectric pipe 33 is comparable to the control in the antenna-substrate distance D, this method can be used to control the crystallinity and deposition rate of thin films to be obtained.

Furthermore, if the impedance cannot be matched due to the relation between the dielectric constant of the plasma and the shape of the antenna, it is possible to make the impedance matched by, for example, controlling the dielectric constant of the feed-through by changing the thickness of its dielectric, or by adding an appropriate impedance element to the ends of above powered conductors 31 and grounded conductors 35 of respective antenna elements 30 or to the conductors 38.

As mentioned above, the thin film formation apparatus 1 can be utilized as a thin film formation apparatus which is capable to deposit high quality a-Si thin film with uniform thickness distribution on large substrates. Above a-Si thin film is suitable for the use in solar cells, therefore, the above thin film formation apparatus 1 is suitable to be utilized as solar cell production apparatus. Moreover, as higher conversion efficiency can be obtained by the use of tandem structure solar cells, where a-Si solar cell is stacked on μc-S solar cell, than in case of a-Si used individually, the above thin film formation apparatus 1 can be utilized as the thin film formation apparatus for the formation of tandem structure solar cells.

Furthermore, in the embodiment mentioned above, the number of the film-deposition chamber 10 was explained and illustrated as being one, however, the number is not limited to this. For example, it is possible to arrange a number of deposition chambers 10 in line, for p-type, i-type and n-type depositions separately, repeat the carrying in and out of the substrate carrier (not shown) to the respective deposition chambers 10, and to carry out an efficient production of, for example, solar cells for the use in photovoltaic power generation.

While this invention has been described with reference to specific embodiments, this invention is not limited to the above embodiments. It should be apparent that numerous modifications and variations can be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.

INDUSTRIAL APPLICATION

According to the above invention, plural plasma sources can be arranged in a

limited space with substrates facing to them, and uniform plasma can be generated between respective plasma sources and the substrates, simultaneous deposition on a number of substrates with uniform properties and thickness distribution can be performed, enabling efficient production of thin films.